

\$26. Development of Large-current Aluminum-alloy-jacketed Nb₃Sn Conductor for FFHR

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A new large-current Nb₃Sn conductor for the LHD-type fusion reactor, FFHR-d1 has been developed that has an aluminum-alloy jacket to support an electromagnetic force¹⁻⁵. The manufacturing process of the conductor is unique in that a jacketing process is performed after reaction heat treatment of the Nb₃Sn cable. This process, which we term the “react-and-jacket” process, imparts the conductor with a high critical current (I_c) because the compressive strain induced in the Nb₃Sn filaments due to the thermal contraction of the jacket material is reduced. This conductor will be wound after the reaction heat treatment to form a magnet. This manufacturing process, the so-called “react-and-wind” process, is more attractive than the conventional wind-and-react process used to fabricate large magnets (e.g., fusion magnets) with Nb₃Sn superconductors because it does not require a large furnace for the reaction heat treatment.

Figs. 1 and 2 show a photograph and schematic diagram of the developed conductor for FFHR-d1. The design current and its density are 100 kA at 12 T and 40 A/mm², respectively. The Rutherford cable consists of 216 bronze route Nb₃Sn wires with diameters of 1.6 mm. The heat-treated cable and low-melting-point metal, Sn-Bi as fillers were embedded in the aluminum-alloy jacket. The two jacket halves were welded each other by friction stir welding (FSW), which does not damage the cable⁴. The final section size is 25 mm x 100 mm. The target I_c of the conductor is 200 kA at 12 T. This target can be achieved by optimizing the cross-section structure and the heat-treatment condition of the strands. The optimization will be conducted in FY2013. However, the conductor developments in FY2012 have demonstrated that it is possible to fabricate a large-current conductor for a fusion reactor.

Fig. 3 shows the schematic diagram of a conductor for FFHR-d1. The conductor has the same configuration as the developed conductor, except that the cable is sandwiched between high-purity-aluminum strips. The aluminum strips has an important role in reducing the hot spot temperature during a quench. Simple calculation using a heat-balance equation suggests that 2 mm-thick aluminum strips can reduce the hot spot temperature down to 150 K, which does not damage the magnet.

The conductors will be cooled by means of indirect-cooling with saturated liquid helium³. To prevent a temperature increase by the nuclear heating, thinner insulator should be developed. This is still an issue for indirect-cooled conductors.

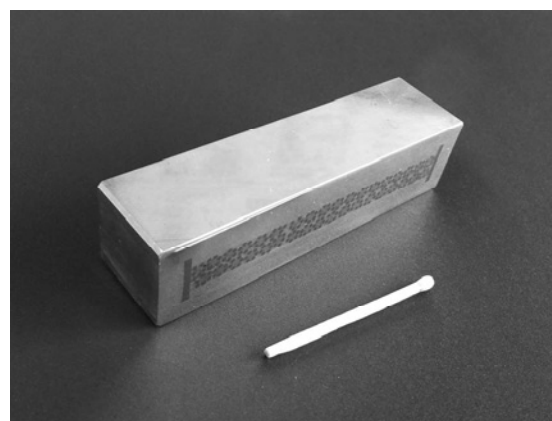


Fig. 1. Photograph of the developed conductor.

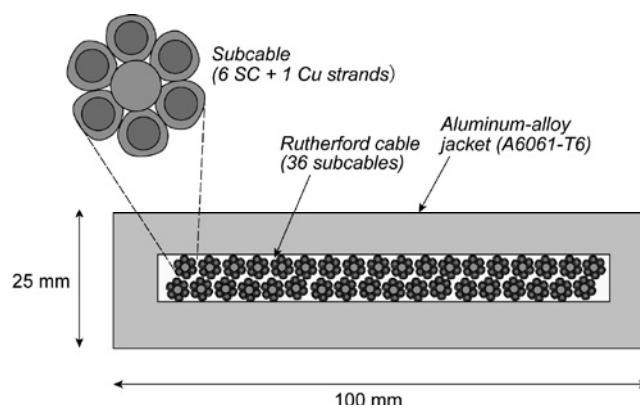


Fig. 2. Schematic diagram of the developed conductor.

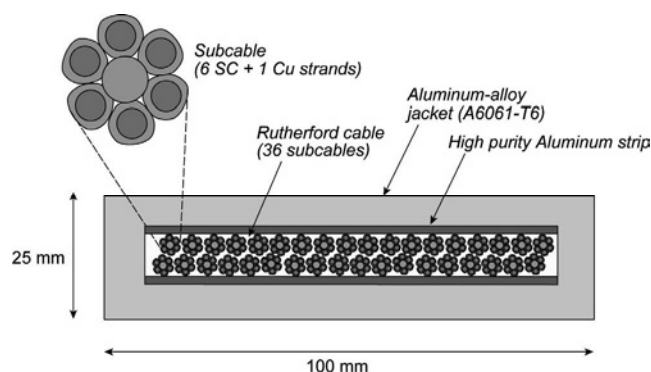


Fig. 3. Conductor for the LHD-type fusion reactor, FFHR-d1.

- 1) Takahata, K. et al.: Cryogenics **51** (2011) 397.
- 2) Tamura, H. et al.: Plasma and Fusion Res. **5** (2010) S1035.
- 3) Takahata, K. et al.: Fusion Eng. Des. **82** (2007) 1487.
- 4) Sugimoto, M. et al.: IEEE Trans. Appl. Super. (2012) 4802905.
- 5) Takahata, K. Et al.: Plasma and Fusion Res. **8** (2013) 2405008.